How to Write a Scientific Paper

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Abstract

This document describes a general outline for writing a scientific research paper. Even though this document does not follow any specific format, it provides general guidelines to writing a paper or technical document. Usually the publisher will provide a set of specific instructions for the paper formatting (e.g. text and heading fonts, single or double column, references style, etc.) or will state which publication style to follow (e.g. American Psychological Association (APA), Modern Language Association (MLA), etc). Most scientific papers include the following sections: Abstract, Keywords, Introduction, Related Work, Problem Statement, Solution Approach, Set-Up / Configuration of the Study or Simulation, Analysis of Results, Conclusions, Future Work, Acknowledgement, and References. Some of these sections are optional and can be omitted or combined. In this paper we provide description of each of these sections give some examples.

Keywords: scientific paper, research paper, document structure, writing style

1. Introduction

The ability to write and to express thoughts in a clear manner is a vital step on the path to becoming a well-rounded and educated person. However, often students who study scientific disciplines such as computer science, engineering, physics, and chemistry discount this very important skill. This becomes clear when one examines the technical documents written by undergraduate students. This paper provides some general guidelines to assist undergraduate students in writing better technical documents and scientific / research papers.

Why should you care about this? Well, presumably you are writing the paper to sell your work in some way. In the context of a class, you are trying to convince your Professor that you have done a good job. In the context of a paper you publish at a conference or in a journal, you want to convince others of exactly the same thing. Write a poor paper and people may dismiss your work out of hand. Write a good paper and you may succeed in publicizing your work to a large audience.

Most scientific / research papers are divided into several sections, such as Abstract, Keywords, Introduction, Related Work, Problem Statement, Solution Approach, Set-Up / Configuration of the Study or Simulation, Analysis of Results, Conclusions, Future Work, Acknowledgement, and References. While the actual section names may differ from those mentioned above, the content of the individual sections should generally match this outline. For example, the Introduction will introduce the reader to the general issues addressed in the paper, while the Set-Up / Configuration of the Study describes how the study of the proposed solution was conducted. To simplify this document, we will use the section names mentioned above.

In the first two paragraphs of this section, we have provided an example of the kinds of information included in the Introduction. In the remainder of this section, we will provide a brief description of the Abstract, Keywords, and Introduction sections.

The *Abstract* is a short description (e.g. a third of a page) of the problem and proposed solution or approach to the solution presented in the paper. The purpose of the abstract is to provide a brief summary of the work that will enable the reader to quickly determine whether he or she wishes to read the rest of the paper. Thus your abstract should provide a good overview of the paper, in a way that may entice the reader to keep reading.

The *Keywords* section has a similar purpose: to help those who are searching for work just like yours find your paper. Keywords list (as individual words or short phrases) the particular areas of study that your paper covers, and are often used for electronic searches. Typically someone finding a set of papers based on keywords will then read the abstracts to further narrow the list. The Keywords section may be omitted.

The *Introduction* section is present in almost every scientific document and it is usually about one or two pages long or 5% to 10% of the paper. In this section the authors introduce the problem being addressed in the paper and describe its importance and relevance to the field of study. In addition, at the end of this section the authors often describe the structure of the paper.

The general formatting requirements such as the size, font, spacing, indentation, layout, format of the paper title, section and subsection headings, text on the paper, paragraphs, tables, figures, equations, references, etc. are usually provided by the publisher in the form of the document template or a set of formatting instructions. It is critical that authors pay close attention to these requirements; the publisher may reject a paper simply because the authors did not follow the formatting instructions.

The rest of this paper is organized as follows: each section starts as a section of a regular research paper and then provides a brief description of what that section should contain. Specifically, section 2 discusses other sources that the student may use to learn how to write a scientific document and provides a general description of the Related Work section. We introduce the problem and describe our proposed solution approach in sections 3 and 4, respectively. The paper concludes and describes directions for the future work in section 5.

2. Related Work

The issue of properly structuring and writing a scientific document comes up each time anyone starts preparing their work for publication. There are numerous guidelines and articles that attempt to address this issue. Most of these articles address a specific publisher's formatting requirements such as document style for publishing in ACM Journal or Transactions [1], American Sociological Association (ASA) references format [2], Eastern Michigan University's collection of links on "How to Cite/ Format

References for Research Papers" [3], "A Guide for Writing Research Papers based on Styles Recommended by The American Psychological Association" [4], "A Writer's Practical Guide to MLA Documentation" [5], and many others. Unfortunately we were unable to find any sources that provide general instructions on how to write a scientific / research paper. The primary goal of this paper is to provide students with the guidelines to structuring and writing a scientific / research paper, instead of providing a specific set of formatting instructions.

Generally, the *Related Work* section is placed either immediately after the *Introduction* or at the end of the paper immediately before the *Conclusions and Future Work* section. When placed early on, it helps the reader better understand the problem discussed in the paper by briefly introducing a variety of other approaches to solving the problem. When placed near the end, it allows the reader to compare and contrast the proposed solution with other research performed in the field. The Related Work section is usually present in the majority of research and scientific publications. This section is not very long and generally is limited to not more than three pages or 10% to 20% of the paper.

3. Problem Statement

The Computer Science Department at Rowan University strongly encourages students to participate in ongoing faculty research. However, the department does not have a graduate program, which makes it more difficult to include student participation in research projects. Beyond understanding the key computer science concepts, students must also be able to clearly and concisely express their thoughts. While most of the Computer Science students have all the necessary technical skills to do the research work, they often have trouble writing down or describing the work they performed. Writing is among of the most important skills required to become a good researcher because it is vital to share the research work with the others. In this paper we are trying to address the problem of teaching the undergraduate student majoring in a technical discipline how to write a scientific/ research document.

The *Problem Statement* section is also fairly short, generally about one-half to two pages long or 5% to 15 % of the paper. Unlike the Introduction, which describes the general problem, this section provides specific details about the problem, often introducing a precise mathematical definition. While there may not be a section titled "Problem Statement," a problem description is a required part of any paper. If the paper does not include the Problem Statement section then usually the problem description is provided as one or more separate paragraphs or as a sub-section in the Introduction or in the Solution Approach sections.

4. Solution Approach and Methodology

To help student write better scientific/ research papers we decided to write a paper that would serve as a template for structuring and writing technical documentation. We

believe that such a paper will help students simplify the process of organizing and structuring their papers. Furthermore, such a document will clearly identify for the students the types of information they need to include in the paper.

The methodology for this project was as follows: Dr. Lobo came up with the idea of the project, identified several sources that contain information on the topic, and subsequently asked Dr. Hnatyshin, a junior faculty in the department, to create such document. Dr. Hnatyshin searched the web to find other sources on the topic, examined these sources, determined the structure of the paper, wrote the paper, and forwarded the first draft of the paper to Dr. Lobo for review. After the review of the first draft, Dr. Hnatyshin introduced proposed corrections and forwarded the document to the rest of the department. After the second round of reviews, the paper was corrected and posted on the Computer Science web-page to be accessed by all the students.

Since this paper does not include a study of any kind, the sections on *Set-up / Configuration of the Study or Simulation* and *Analysis of Results* are omitted.

The *Solution Approach* describes the rationale and the details of the solution to the problem. This section usually takes the main portion of the paper and generally ranges between one and 10 pages, or about 40-50% of the material. This is a mandatory section and generally consists of several logically connected sub-sections. Often one of the subsections in the Solution Approach describes the methodology of the solution or the steps to solving the problem. The size of the Methodology part of the paper varies depending on the topic and can range anywhere from a single paragraph to several pages.

Even though we have not conducted any studies for this paper, the authors of scientific/ research papers frequently describe the evaluation of the proposed solution to the problem. Whenever the paper describes a study it is important to carefully describe how the study was conducted and what assumptions where made. The rule to writing this section is to include enough details that anyone else who would like to repeat the study can do so based on the description you provide.

The *Analysis of Results* section usually follows the *Set-up / Configuration of the Study or Simulation*. This section provides a careful analysis of collected results identifying various observed phenomena and highlighting the importance of made observations. The sections that describe the study and analysis of results are very important and usually take several pages, anywhere between 15% and 30% of the paper.

5. Conclusions and Future Work

This paper provides a general outline for writing a scientific paper. It lists and describes the most important parts and sections that must be present in any scientific/ research paper or technical document. We plan to distribute this paper among other faculty and students at Rowan University and based on their feedback update the paper and hopefully improve its quality.

The *Conclusions* and the *Future Work* sections summarize the paper, draw conclusions about the proposed solution, and chart future directions of the research. These sections are mandatory but usually are not very long, ranging anywhere between one-half a page to 2 pages or 5% to 10% of the paper.

Occasionally, the authors list people and organizations that helped complete and publish the work. This information usually goes into the *Acknowledgement* section, which is only a few lines long.

The final section of any paper lists the references used to do the research and write the paper. There are various standards for compiling the references and listing them in the paper. The authors refer the reader to the web links listed in the References section for further details. However, here are a few key rules:

- There are various formats for citing the references in the text of the paper and listing them in the Reference section,
- Different types of references (e.g. journal, books, conference paper, web-sites) have different formats for citing them in the Reference section,
- The references are usually ordered either alphabetically or by the order they are mentioned in the text,
- It is important to include the date of the last access for all the Internet article references.

References

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